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16. ABSTRACT

The paper describes an aerosol precharger that can provide a charging environment with relatively high unipolar ion density for particulate matter having high electrical resistivity. The result is a much higher level of charge on the particles than can be achieved by a conventional electrostatic precipitator which is limited by back corona to a low current density. Used in conjunction with a downstream collector operated at a low current density and high electric field strength, the precharger may be of significant value in the collection of high resistivity particulate materials.

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A Novel Device for Charging High Resistivity Dust

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When particulate material having high electrical resistivity ($\geq 5 \times 10^{10}$ ohm cm) is introduced into an electrostatic precipitator (ESP), it is at first deposited on the grounded electrodes in the same manner that a lower resistivity dust is collected. Once a deposit of dust begins to build up, the corona current must pass through the layer of high resistance, and in some regions the product of the current density and the resistivity may yield electric field strengths great enough to cause breakdown in the dust layer. The localized high current density resulting from that breakdown causes convergence of the corona current to the breakdown site, and may result in sufficient ionization activity to develop a corona discharge at or near the surface of the dust layer. This "back corona" injects into the active volume of the precipitator ions of polarity opposite from those generated at the corona discharge electrode. With ions of both positive and negative polarity in the active region of the precipitator, the particle charging process is severely degraded.[1]

Southern Research Institute, with the support of the Particulate Technology Branch, Industrial Environmental Research Laboratory, U. S. Environmental Protection Agency, Research Triangle Park, has been investigating a two-stage approach to solution of the problem of precipitating high resistivity particulate materials.[2] In a two-stage ESP, particle

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charging occurs principally in the first stage, or precharger. Particle collection occurs in the second stage, or collector, which would be designed to operate at a relatively low current density and high electric field strength. Thus it is in the precharger that back corona poses the greatest difficulty.

Precharger Design Concept

The precharger design for suppression of back corona is based on a simple wire-plate electrode geometry, with the addition of perforated screen electrodes parallel to the plates, as illustrated in Figure 1. A high voltage applied to the corona wire will bring about corona conduction. In general, part of the current will go to the plate and part to the screen, depending on the relative potentials at each. If the plate is grounded and the screen is set at a potential having the same polarity as that of the corona wire, ions moving toward the plate will tend to be repelled away from the screen. If the magnitude of the potential at the screen is great enough, the screen current may go to zero, while a considerable corona current passes through the openings in the screen, proceeding from the corona wire to the plate.

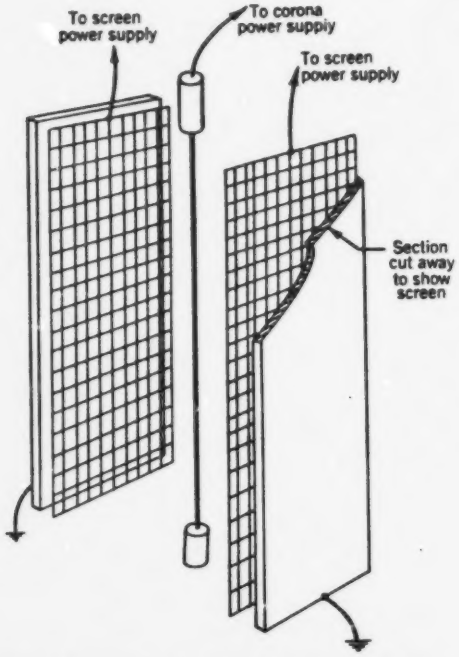

Figure 1. Arrangement of electrodes in the high resistivity particle precharger. This is a conceptual sketch, not drawn to scale.

Now if a high resistivity dust is introduced into the system, some of the dust may be precipitated on the plate electrodes. Very little dust will be deposited on the screen, because the charge on the particles will be the same as that of the screen, and hence there will be a repulsive force between the particles and the screen electrodes. If enough dust builds up on the plate electrode, back corona may occur. The ions resulting from back corona will have polarity opposite from that of the screen, so that in moving away from the plate they will tend to be attracted by the screen and captured. Thus, the ion density in the space bounded by the screen electrodes can remain essentially unipolar, even if a substantial amount of back corona activity occurs at the plate electrodes.

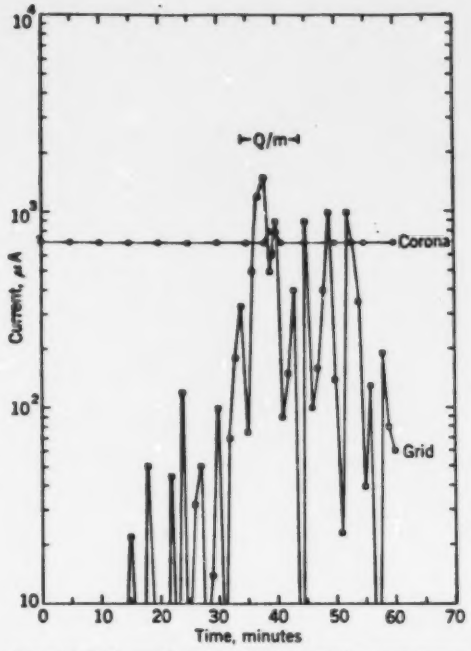

Figure 2. Back corona suppression test and Q/m measurement at 100°C, 1.2% H_2O, j = 94 nA/cm², and Q/m = 2.86 × 10^{-6} C/g. Dust loading is approximately 7 g/m³ (3 gr/ft³).

Experimental Work

Laboratory scale and small pilot scale prechargers, incorporating the screen electrode as described in the above paragraphs, have been fabricated and tested. Operating conditions in the presence of high resistivity dust were in accordance with predictions based on the theoretical concept, and good particle charging results were achieved with dust resistivities in the range of 10^{12} to 10^{13} ohm cm.

The general procedure for operating the precharger is as follows: first, turn on the corona discharge electrode's power supply, and establish a steady corona current in the clean system; next, turn on the screen voltage, and increase it until the screen current falls to zero. These two steps establish the clean plate operating conditions. Now introduce dust laden gas into the system. As back corona begins, changes are noted in the screen current; however, no adjustments in applied voltages are required unless an increase in current to the corona discharge electrode is observed. If the corona current begins to rise, bring it back to its initial value by adjusting the screen voltage. In any test, back corona suppression was considered successful if the corona current could be kept constant, regardless of fluctuations in the screen current. Confirmation of this viewpoint by particle charging measurements will be discussed later in this paper.

Figure 2 illustrates the electrical behavior of the pilot scale system, operated over a period of 1 hr. The dust load passing through the system was approximately 6 g/m³ (2.6 gr/ft³) of redispersed fly ash, with a measured MMD of 19 μm. The gas temperature was maintained at 100°C, producing a particle resistivity of approximately 1.4 × 10^{12} ohm cm. (Resistivity was determined by ASME-28 method, and by in situ measurement). Total gas flow rate was about 0.71 m³/sec (1500 acfm).

During the test the corona current remained constant, except for a small deviation which occurred about 40 min after the start of the experiment. The total corona current of 700 μA corresponds to an average current density at the plate of 94 nA/cm². As in typical operation of the system, back corona effects, as indicated by a sharp rise in screen current, began

at 10 to 15 min after the dust feed system was turned on. Extremely large fluctuations in the screen current are evidence of a high level of back corona activity.

The notation Q/m on Figure 2 indicates the interval of time during which a measurement of particle charging effectiveness was made. Particles were collected on a silver mesh filter mounted in a plastic filter holder, fitted with a nozzle for isokinetic sampling. The filter was connected to an electrometer so that the charge accumulation could be monitored during the collection process. A foil shield, grounded through a 10 megohm resistor was wrapped around the body of the filter holder to prevent buildup of charge on the insulating plastic. Upon completion of the sampling period, the total accumulated charge was recorded and the captured dust sample was weighed. These data were then used to calculate the ratio of charge to mass Q/m for the sample.

In the experiment associated with Figure 2, the measured value of Q/m was approximately 2.9 μC/g. Theoretical values of charge for the particle distribution used in this test showed good agreement with the experimental value. Since the theory is based on charging by unipolar ions, it appears that back corona suppression by the action of the screen electrode was successful. Without the screen grid the corona current density at the plate would be limited to the level at which back corona occurs. That value would be of the order of 1% of the corona current used in the experiment above.

Experiments with a device similar to the new precharger, but lacking the corona suppression screen, provide for a comparison with the conventional technology.[2] Maximum charging levels for low resistivity dusts ($<10^{10}$ ohm cm) in the "conventional" device are three to five times greater than those achieved in the high resistivity experiments with the new precharger. But when a high resistivity dust was introduced into the "conventional" device the measured charge to mass ratio dropped to a value less than one tenth of that measured with a similar dust in the new precharger. The new device thus provides a significant advantage where back corona is a problem.

Summary

The aerosol precharger described in the preceding paragraphs can provide a charging environment with relatively high unipolar ion density for particulate matter having high electrical resistivity. The result is a much higher level of charge on the particles than can be achieved by a conventional electrostatic precipitator which is limited by back corona to a low current density.[3] Used in conjunction with a downstream collector operated at a low current density and high electric field strength, the precharger may be of significant value in the collection of high resistivity particulate materials.

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